



# Large Dams and Hydro Electricity

Price  
30p

## Background

Water flowing through a turbine will generate electricity in proportion to the volume of water and the height the water falls\*. It is not necessary to build a dam. At Niagara some river water is simply diverted round the Falls through a tunnel to a power station. However most hydro electric schemes use dams to raise the water level to increase the power and create storage reservoirs which smooth out the river flow and allow generation for more of a year.

Power stations do not necessarily have to be built at the foot of a dam though many are. Pipelines and tunnels can convey water down a river valley or through hills to lower valleys to increase the 'head' and thus the power. The Snowy Mountains scheme in Australia has 15 large dams and 145 km of tunnel.

Usually dams serve several purposes. 67% of the water in dams worldwide is used to irrigate crops, 19% for industrial use and 9% for public water supply. Any electricity generated will help pay for the works but generation may not have priority use of the water.



*Kariba Dam, on the Zambezi*

Rivers carry more water in winter than summer in northern latitudes and more in the wet than dry seasons in the Tropics. Besides storing water reservoirs reduce the risk, destruction and danger of flooding. In dry periods when river levels fall water can be released for farmers and others for abstraction downstream or for fish to survive and navigation continue. Many early dams in England and Wales as at Vrynwy and the Elan Valley in Wales, Haweswater in the Lake District and

*\* Electricity generated (kW) is height (metres)  $\times$  flow ( $m^3/sec$ )  $\times$  9.81  $\times$  efficiency (c. 50% for small, low head turbines, 95% large, high head). A small 2m high weir with  $1m^3/sec$  flow would produce c.10 kW*

many in the Pennines, were built to provide safe drinking water for the growing cities of Liverpool, Birmingham, Manchester and so on. Water was taken directly from the reservoirs, with turbines only added to make use of surplus water in winter.

Because hydro electricity is renewable and many uses met (which now include recreation and wildlife reserves), and because their reservoirs provide the *only* substantial means by which energy can be *stored* at present, hydro electricity was, and despite recent criticism remains, the premier source of electricity. Indeed it is the only globally significant renewable source. In 2005 it provided 16% of global electricity, more than nuclear (15.2%). It provides over 90% of electricity in both Norway and Brazil and over 50% in Austria.

## Some history

Permanent or temporary dams have been constructed since the dawn of the early civilisations in the Tigris and Euphrates, Ganges and Nile valleys to divert water into irrigation channels for crops in the fields. Indeed irrigation technology made those civilisations possible, even though an imperfect understanding of how salt levels can build up in the soil through evaporation is thought to have led to the collapse of the Babylonian civilisation. Amongst the oldest known dams are the Nimrod earth dam on the Tigris north of Baghdad; a Roman dam using lime cement built around 100 AD at Ponte di San Mauro; and an arch dam near the ancient city of Qum built in 1280 AD by the Mongols which was 25 metres high. In the UK after the Conquest, dams were used mainly to create pools to power mill wheels. Most dams were of earth with an inner core of clay 'puddled', that is compacted by foot, to provide a watertight seal. A step change in the UK came with the construction of the Vrynwy Dam in the 1880s. Vrynwy is a massive wall of concrete resisting the water pressure by gravity: ie by its weight. It was designed by the most famous water engineer of all time, Thomas Hawksley, assisted by another eminent engineer, Deacon. Vrynwy opened the door to higher, safer and more elegant structures and dam technology was developed rapidly by UK engineers who built dams across the Empire and by Americans (who had learnt much from the Spanish) and the French. High dams in narrow valleys nowadays use 'arch' configurations to reduce the material needed (see Kariba, opposite). Dams in wider valleys are usually made of earth or rock which support an impermeable 'core' of concrete, asphalt or clay.

Dams over 100 metres high and a kilometre or more long are now common. The highest is 300 metres high. The largest reservoirs are huge. That behind the Grand Coulee Dam, the largest in the USA, stretches back 240 km. Lake Kariba is 300 km long. The Itaipu Dam reservoir on the Parana River on

## An ALDES Briefing Note

Last updated February 2009

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the Brazil/Paraguay border is 170 km long. The Itaipu had the largest hydro electricity capacity in the world at 12,600 MW producing 75 Terawatt hours\*\* (TWh) of electricity/year, 15 times as much as the total hydro in the UK. (Hydro contributes some 1.3% of the UK's electricity). The 3 Gorges Dam on the Yangtze River in China, however, is bigger. When full the reservoir will be almost 600 km long. By 2011 the 18,200 MW of turbines should be generating 85 TWh/y. There are now 45,000 large dams in the world, defined as more than 15 metres high or impounding more than 3 million m<sup>3</sup> of water. Almost half are in China.

## Criticisms

Criticism of large dam projects has been mounting. The Pergau Dam in Malaysia was condemned because it was alleged that UK assistance was dependent on Malaysia buying UK arms; the Three Gorges Dam principally for the displacement of at least 1 million people and inadequate plans for their resettlement; and the Ilisu Dam in Turkey for displacement of people, the flooding of historic sites and threatening international conflict with Syria and Iraq, the countries downstream.

The principal downside of dam construction is that land will inevitably be flooded in valley bottoms where it will often be of good quality and heavily populated. Farmers will be dispossessed, houses and agricultural land lost and communities disrupted. There are 7 other main problems. First, archaeological sites can be threatened, though they may not be lost. The Egyptian temple of Abu Simbel was moved to a new site on the shore of the rising Lake Nasser. Second, fish migration will be impeded. Fish 'ladders' only mitigate some of the effects. Third, water removed for public water supply or irrigation will be lost to the river downstream. Indeed so much water is removed from the Colorado River in America that none reaches the sea. Fourth, international tension can rise where a river runs through several countries who can not agree on 'equitable' shares. This is an acute issue between Israel and Jordan over the River Jordan which rises in the Golan Heights. Fifth river sediment or silt, which can contain organic material and therefore provide fertilizer, will settle into the reservoir, instead of spreading over the flood plain. Silt will slowly fill the reservoir up though smaller reservoirs can be flushed using drains in the base of the dam. Elsewhere flood flows, carrying the heaviest load of silt, can be diverted into 'silt traps' or basins where the silt settles out before the water continues. Good management of a catchment to reduce the loss of soil can also help. Even so it is commonly assumed reservoirs have finite lives, perhaps no more than 100 years. Sixth, the wildlife habitat will change though not necessarily for the worse. Reservoirs can become useful fisheries and support extensive bird life. Seventh, dams are considered vulnerable to earthquakes and the weight of the water in a filled reservoir can be so great they actually *cause* them. Lake Kariba, which weighs 180 billion tonnes, caused several earthquakes measuring 5.0 on the Richter scale. Engineers need to take weight into account. It was calculated the Mangla Reservoir in Pakistan would cause the ground to settle 1.5 metres at the dam, so the gradients of the irrigation channels from the dam had to be adjusted.

## Resettlement

Of all the issues the one of resettlement is the most vexing. People have always and naturally protested against new dams but in the past authorities applied the doctrine of the 'greater good' and usually went ahead. Construction of the Kariba Dam on the Zambezi in the 1950s however caused much concern. The reservoir valley was difficult to penetrate and the 50,000 native tribesmen with their unique lifestyle as well as large numbers of game animals proved difficult to locate and move out of the way of the rising water. Even now, 40 years later, resettlement plans often appear poorly thought out and compensation derisory. More sensitivity must be shown. The city of Sydney for example is buying agricultural land as it comes on the market for a future reservoir.

## Greenhouse gas emissions

Until a few years ago hydro electricity was lauded as being CO<sub>2</sub> free. Then Canadian researchers worked out that much global methane came from decaying vegetation in lakes and concluded that methane from man made reservoirs must be significant. They then claimed that in tropical countries such as Brazil the effect on global warming of the released methane from reservoirs was *greater* than would have occurred had the electricity been generated from gas power stations because methane is at least 20 times as powerful a greenhouse gas as CO<sub>2</sub>. They conceded savings were still made in reservoirs in temperate climates.

This finding remains controversial and there are a number of mitigating measures that can be used. Banks can be trimmed to reduce the weight of organic debris reaching the reservoir, and reservoirs can be aerated to convert the methane to CO<sub>2</sub>. Some water supply reservoirs in the UK are already aerated in the autumn when, as the surface water cools, it becomes denser than the water beneath causing the reservoir water to 'overturn' bringing some of the bottom mud to the surface and allowing trapped methane to escape.

## The future

It would be a tragedy if failure to address the human rights issues of resettlement and resolve the issue of methane release prevented further construction of large dams. Mankind is steadily pushing other species off the planet and until population growth is reversed people will require more food and water to irrigate the land. Currently 40% of food production is dependent on irrigation yet many countries already face fresh water 'stress'. While we must always strive to use water efficiently, dams remain the best way to increase the total water available. Additionally, reservoirs provide the best current means of 'storing' electricity and so balance out the unreliable supplies from wind and solar energy so maximising the amount of electricity from those sources. Three existing hydro electric schemes in Scotland are being updated and a new scheme at Glendoe near Fort Augustus is on schedule to add 100 MW capacity and 180 MWh/y of 'green' electricity by early 2009. Including Glendoe, Scotland has about 1500 MW of hydro electricity and a report in 2008 listed 128 more sites (mostly small ones) which could increase this to 2000 MW. The potential elsewhere in the UK is limited but *properly planned* projects here and around the world, should be encouraged.

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\*\*A Terawatt-hour is 1000,000,000 kilowatt hrs, or 'units' of electricity. The UK used 375 Terawatt hours of electricity in 2006.